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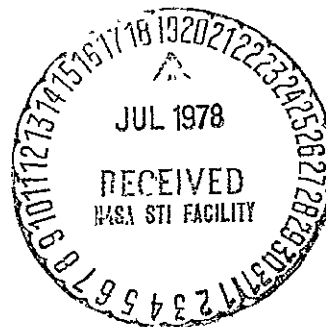
(NASA-CR-157235) RESEARCH IN SPACE PHYSICS
AT THE UNIVERSITY OF IOWA Annual Report,
1977 (Iowa Univ.), 63 p HC A04/MF A01

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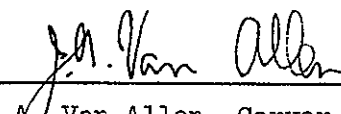
Department of Physics and Astronomy
THE UNIVERSITY OF IOWA

Iowa City, Iowa 52242

RESEARCH IN SPACE PHYSICS
AT THE UNIVERSITY OF IOWA

ANNUAL REPORT FOR 1977

Prepared by



J. A. Van Allen, Carver Professor of Physics and
Head, Department of Physics and Astronomy

July 1978

1.0 General Nature of the Work

1.01 Our broad objective is the extension of knowledge of the energetic particles and the electric, magnetic, and electromagnetic fields associated with the earth, the sun, the moon, the planets, and the interplanetary medium.

1.02 Primary emphasis is (a) on observational work using a wide diversity of instruments of our own design and construction on satellites of the earth and the moon and on planetary and interplanetary spacecraft and (b) on phenomenological analysis and interpretation.

1.03 Secondary emphasis is (a) on closely related observational work by ground based radio-astronomical and optical techniques and (b) on theoretical problems in plasma physics as relevant to solar, planetary, and interplanetary phenomena.

1.04 Specific fields of current investigation are the following:

(a) All aspects of the energetic particles that are trapped in the earth's magnetic field and are transiently present in the outer magnetosphere including the magnetospheric tail of the earth; and of the solar, interplanetary, and terrestrial phenomena that are associated with these radiations -- solar flares, interplanetary magnetic fields and plasmas, aurorae, geomagnetic storms, corpuscular heating of the atmosphere, electromagnetic waves and magnetostatic and electrostatic fields (both constant and variable)

in the magnetosphere, plasma flows in the magnetosphere, and the ionospheric effects of particle precipitation. This field of research was originated to a major extent by this laboratory.

- (b) Corresponding studies of the magnetospheres of Jupiter, Saturn, and possibly Uranus.
- (c) Origin and propagation of very low frequency radio waves in the earth's magnetosphere and ionosphere.
- (d) Energetic electrons, protons, alpha particles, and heavier nuclei emitted by the sun; the interplanetary propagation and acceleration of these particles, including the effects of shock waves and the generation of electrostatic and electromagnetic waves in the interplanetary medium; and the access of such particles to the earth's magnetosphere.
- (e) Solar modulation and the heliocentric radial dependence of the intensity of galactic cosmic rays.
- (f) Radio-frequency emissions from both the quiescent and flaring sun and the implications thereof on the nature of the chromosphere and corona and on the acceleration and emission of energetic particles in solar flares.
- (g) Shock waves in the interplanetary medium.
- (h) The theory of wave phenomena in turbulent plasmas including the interplanetary medium and of the origin of super-thermal particles.
- (i) Dekametric and decimetric radio emissions from Jupiter and the relationships of same to its magnetosphere.

(j) Radio astronomical study of pulsars, flare stars, and other stellar sources as an extension of our work on planetary magnetospheres and the sun.

The attached bibliography lists specific investigations completed and published in 1977.

2.0 Currently Active Projects

2.01 Hawkeye 1 (Explorer 52, 1974-040A)

This satellite and its principal scientific instruments were designed and built at the University of Iowa and launched into a highly eccentric, nearly polar orbit from the Western Test Range on 3 June 1974. During 1977 it continued to operate properly and to yield excellent magnetospheric data despite a considerable reduction in support for data acquisition. A special compilation "Hawkeye 1. Bibliography" of 2 May 1978 is attached to this report. [Hawkeye 1 re-entered the earth's atmosphere, as predicted, on 28 April 1978 after 667 orbits and nearly forty-seven months of successful in-flight operation.] Active analysis on the large body of data continues as a major activity of the laboratory.

[Van Allen, Frank, Gurnett, Chen, Craven, Kurth, Baumback, Green, Randall et al.]

(Support by Langley Research Center/NASA, Goddard Space Flight Center/NASA, and Office of Naval Research)

2.02 Pioneers 10 and 11

The two spacecraft, both carrying University of Iowa energetic particle detectors, were the first and so far only ones to make encounters with Jupiter. The large body of data that they yielded has produced dramatic advances in knowledge of Jupiter and has also stimulated a fresh wave of theoretical as well as ground-based astronomical work on this planet and its satellites. They have also yielded a unique body of data on the cosmic radiation and the physical properties of the interplanetary medium to unprecedented distances from the sun. Both spacecraft and most of the scientific instruments (including ours) continue to operate properly. Data are received on a daily basis (~ 8 hours of data per day). Pioneer 10 is on a hyperbolic escape orbit from the solar system with heliocentric distances as follows: 23 January 1977, 12 AU; 30 September 1977, 14 AU; 7 June 1978, 16 AU; 13 February 1979, 18 AU; 24 October 1979, 20 AU; and March 1983, 30 AU. It is expected that good quality data will continue to be received (at bit rates ≥ 32 bits/sec) through 1979. Current upgrading of the 64-meter NASA stations may make it possible to continue data acquisition into the early 1980's.

Pioneer 11 is targeted for encounter with Saturn on 1 September 1979. Samples of its heliocentric radial distances are as follows: 5 November 1977, 6 AU; 17 May 1978, 7 AU; 29 November 1978, 8 AU; and 18 June 1979, 9 AU. Following encounter with Saturn, it will also escape from the solar system.

The prospective survey of Saturn's magnetosphere for the first time is the element of highest future interest in the Pioneer 10/11 program. Meanwhile, the cosmic ray intensity measurements by both spacecraft are contributing to the solution of the long standing, classical problem of the propagation of galactic cosmic rays in the solar system. Also, an instrument on Pioneer 11 is providing unique data on the acceleration of protons by shock waves in the interplanetary medium and on the propagation of solar electrons and protons at great distances from the sun.

Further work on the interpretation of the Jupiter encounter data from both spacecraft continues on an active basis.

[Van Allen, Goertz, Thomsen, Pesses, Randall, Sentman, and Parish]

(Support by Ames Research Center/NASA and Office of Naval Research)

2.03 Explorer 47 (IMP-H)(1972-73A)(IMP-7)

This GSFC/NASA satellite of the earth was launched on 23 September 1972 into an approximately circular orbit of initial inclination 17° and semi-major axis $35.3 R_E$ (earth radii). The orbital inclination of this long-lived satellite had increased to 40.8° by December 1977 with a semi-major axis of $35.4 R_E$ and a period of 12.4 days. Operation is by command only on an intermittent basis following an extended period of nearly continuous data acquisition. It carries a University of Iowa electrostatic analyzer for measuring the energy spectra and angular distributions

of low energy electrons, protons, and heavier ions in the energy range 5 eV to 50 keV. The purpose of the experiment is to further the understanding of geomagnetic storms and aurora by investigating phenomena in the magnetotail of the earth. A significant discovery in the 1974 data was the presence of energetic atomic oxygen (O^+) in the magnetotail, establishing the escape of ionospheric ions into the magnetosphere and their acceleration to energies of the order of several keV.

[Frank, Ackerson, and Yeager]

(Support by GSFC/NASA and NASA Headquarters)

2.04 Explorer 50 (IMP-J)(1973-78A)(IMP-8)

This 317 kg GSFC/NASA satellite was launched on 26 October 1973 into an orbit with inclination 28.2° , radial distances to perigee and apogee 23.8 and 46.4 R_E , respectively, and period 12.2 days. This satellite carries VLF radio receivers and electrostatic particle analyzers from the University of Iowa. A large body of high quality data from both sets of experiments has been acquired, with operations continuing into 1978 on a reduced basis.

[Frank et al. on electrostatic analyzers]

[Gurnett et al. on VLF radio receivers]

(Support by GSFC/NASA)

2.05 Explorers 33 and 35, Explorer 43 (IMP-I) (IMP-6), Explorer 45 (S^3 -A), and Ariel 4 (UK-4)

The operational lifetimes of these five spacecraft have terminated but study of the data from them continues on special

problems. These satellites were operative during periods of high solar activity. Collaborative work with investigators from other laboratories has been and continues to be a valuable feature of the data base.

[Van Allen, Frank, Gurnett, Craven et al.]

(Support by ONR and NASA Headquarters)

2.06 German American Solar Probes (HELIOS-I and II)

The interplanetary spacecraft HELIOS-I was launched successfully from Cape Canaveral on 10 December 1974 by a Titan Centaur vehicle. The heliocentric orbit is near the ecliptic plane with perihelion at 0.3 AU from the sun. The first perihelion passage was on 13 March 1975; subsequent perihelion passages occur at about six month intervals. Helios II was launched successfully on 15 January 1976 into a similar heliocentric orbit. The principal scientific purposes of the two missions are study of particle and field phenomena in the interplanetary medium at distances closer to the sun than have been reached previously. (The perihelion of Mariner 10's orbit was approximately at the orbit of Mercury at 0.39 AU.) One of the three American instruments on each of the two spacecraft is the University of Iowa plasma-wave radio receiver (10 Hz to 15 kHz). Good measurements from both Helios I and II are being obtained. One of the more interesting bodies of results has come from the use of a combination of Hawkeye 1 and Helios observations for direction-finding and tracing solar electron streams in the

interplanetary medium by way of the Type III radio emissions that they excite in the medium. It has also been established that such emissions occur at twice the local electron plasma frequency. Both spacecraft are now in their extended mission phases, with substantially reduced data acquisition.

[Gurnett, Anderson, Odem, Green, and Baumback]

(Support by GSFC/NASA)

2.07 Voyagers 1 and 2
(Formerly called Mariner Jupiter/Saturn
1977 Missions)

The University of Iowa designed and built plasma-wave instruments for both of these planetary fly-by missions and is a member of the investigative team. Voyager 1 was launched successfully on 5 September 1977. It is scheduled to fly-by Jupiter in March 1979 and Saturn in November 1980. Voyager 2 was launched earlier and on a slower trajectory on 20 August 1977. It will fly-by Jupiter in July 1979 and Saturn in August 1981. A possible further option is a fly-by of Uranus in early 1986. Both instruments are operating well, with an exceptionally low level of spacecraft interference. The principal purpose of these investigations is to determine the properties of the plasmas in the magnetospheres of Jupiter and Saturn (and Uranus) by measuring very low frequency electrostatic and electromagnetic waves in situ. Information on the origin of dekametric emissions may be obtained inferentially. Both Voyagers have already yielded valuable new observations on

interplanetary Type III solar bursts and on plasma waves in the interplanetary medium.

[Gurnett, Shaw, Oden et al.]

(Developmental support by ONR and NASA Headquarters)

(Hardware and data analysis support by Jet Propulsion Laboratory/NASA)

2.08 International Sun-Earth Explorers (ISEE)

Two University of Iowa experiments are on each of the two spacecraft of the ISEE-1, ISEE-2 ("mother-daughter") magnetospheric mission (formerly called International Magnetospheric Explorers). Both spacecraft were launched by a single vehicle on 22 October 1977 and were then separated so as to fly independently in the same orbit but separated by a varying distance of the order of 1000 km along the orbit. Special features of this double mission are:

- (a) Sophisticated magnetospheric instrumentation.
- (b) High data rates (S-band) and correspondingly high time- and angular-resolution.
- (c) The capability of separating temporal from spatial effects, especially in the vicinity of the earth's magnetopause and bow shock and in the magnetotail.
- (d) Monitoring of the solar wind, solar energetic particles, and magnetospheric phenomena during a period of increasing and probably maximal solar activity (in ≈ 1980).

The initial orbit of ISEE-1 (NASA) and ISEE-2 (European Space Agency) was as follows:

Perigee altitude	279 km
Apogee altitude	138,108 km (22.65 R_E radial)
Latitude of apogee	21.6°
Local time of first apogee	10.9 ^h
Inclination	28.7°
Period	57.43 hours

Early results from both University of Iowa instruments are of high quality, though the electrostatic analyzer on ISEE-2 failed in mid-January 1978. The other three instruments continue in proper operation.

[Frank, Craven et al., low energy particle differential analyzers]

[Gurnett et al., plasma wave receivers]

(Developmental support by ONR and NASA Headquarters)

(Hardware and data analysis support by GSFC/NASA)

A third spacecraft of the ISEE program (ISEE-C) is scheduled for launch in late July 1978. It is called a "heliocentric" mission because the intention is to place it in a halo orbit near the (L1) Lagrangian point of the earth-sun system, on the line joining the earth to the sun at a distance about 235 R_E sunward of the earth. Thus, it will serve as an "up-wind" monitor of solar wind and other interplanetary conditions free of terrestrial-lunar interference. Gurnett is a co-investigator on the plasma-wave experiment.

2.09 Theory

Theoretical studies are continuing on the propagation and acceleration of solar protons, alpha particles, and electrons in the interplanetary medium; on the emission of X rays and radio noise by the sun; on the generation and propagation of very low frequency radio waves in the magnetosphere and on the relationship of such waves to particle acceleration, diffusion, and precipitation; on shock waves in the interplanetary medium; and on the physical dynamics of the magnetospheres of Jupiter and Saturn.

[Goertz, Shawhan, Thomsen, Sentman, Pesses]

(Support by ONR, NSF, and NASA Headquarters)

2.10 Very-Long-Baseline Radio-Interferometry

A program of VLBI observations has been developed at the North Liberty Radio Observatory in collaboration with Iowa State University/Ames, NOAA/Boulder, GSFC, and the National Radio Observatory in Green Bank, West Virginia. In contrast to most other VLBI experiments, a low frequency, 26.5 MHz, has been selected in order to study solar radio emissions, the dekametric emissions from Jupiter and the structure of the interplanetary plasma and to search for emissions from Saturn. None of the latter has been observed as yet, but significant new results have been obtained on the other three topics.

[Shawhan, Cronyn, and H. Chen]

(Support by ONR, NOAA, and NSF)

The 60-ft antenna at NLRO has been converted to a VLBI receiving station operating at a wavelength of 18 cm (OH line). It has been adopted as an element of the national VLBI network at this frequency. A substantial program of observations is underway.

[Mutel, Benson, and Phillips]

(Support by ONR, Research Corporation, and NASA)

2.11 Large Area Radio Interferometer

During 1972-74 the University of Iowa collaborated with NOAA/Boulder and GSFC in constructing the largest area radio interferometer in the northern hemisphere. Both effective area and angular resolution exceed those of the Arecibo facility. The array is located at Clark Lake, California. The operating frequency is 34 MHz. An intensive program of observations is continuing. Objectives of this work are to study the propagation of solar wind streams through interplanetary space (via interplanetary scintillation of compact radio sources); to observe dekametric radio emissions from Jupiter; and to search for radio emissions from Saturn.

[Shawhan, Cronyn, Rickard, Benson et al.]

(Support by NASA, NSF, GSFC/NASA, NOAA, and U. S. Air Force)

2.12 Hawkeye 2 Proposal (cf. 1976 Annual Report)

After a period of over $3\frac{1}{2}$ years of negotiation with NASA Headquarters and of extensive studies, the University of Iowa

proposal for a Hawkeye 2 mission was rejected on 16 June 1977:

" ... within the current OSS Explorer Program. ... The reason for the rejection of [Hawkeye 2] is that the scientific objectives for this mission overlap those of the Dynamics Explorer (DE) mission. This resulted in [Hawkeye 2] having a lower priority than the Explorer missions that have finally been selected."

The disappointment of this rejection was considerably reduced by the selection of two University of Iowa instruments for the approved Dynamics Explorer Mission.

2.13 Dynamics Explorer (Formerly called Electrodynamics Explorer)

This NASA program envisions a coordinated pair of orbiting spacecraft, one in an eccentric polar orbit with apogee at about $5 R_E$ and another in a circular low-altitude polar orbit. One or both may have orbital adjustment capability. The central theme of the DE program is study of the physical coupling of the magnetosphere, ionosphere, and neutral atmosphere of the earth. Based on proposals submitted originally in November 1974, two University of Iowa experiments for DE have been selected and provided with start-up funding. One of these is a set of global auroral imaging instruments and the other a set of plasma-wave ELF-VLF receivers. Both are similar to those proposed for Hawkeye 2 and both will be on the eccentric orbiter. The present status is one of design, engineering definition, and prototype construction. The tentative launch date is late 1980.

[Frank and Ackerson, auroral imaging photometers]

[Shawhan and Gurnett, plasma wave instrument]

(Proposal and engineering design support by ONR and NASA Headquarters)

(Hardware support by GSFC/NASA)

2.14 Auroral Imaging

During the past four years a major effort has been devoted to developing a new type of sensitive spot-scanning "camera" for global scale imaging of auroral emissions and other low-light-level emissions in selected wavelength bands from the earth's atmosphere. This work has included the outfitting of an optics research laboratory; the purchase and development of suitable sources; the construction and testing of prototype systems; and the development of computerized handling of imaging data. This work provides the basis for the global auroral imaging experiment for the Dynamics Explorer. The instrumentation is also applicable to other spinning spacecraft such as a Pioneer class spacecraft during planetary flybys or in planetary orbits.

[Frank and Ackerson]

(Developmental work supported by Office of Naval Research)

2.15 Galileo (Formerly called Jupiter Orbiter with Probe Mission)

This JPL/NASA mission was approved and given start-up funding in late October 1977. The scheduled launch date (shuttle with

inertial upper stages) is January 1982 with arrival at Jupiter, after a close fly-by of Mars, in July 1985. During the approach phase an entry probe will be released. The mother spacecraft will be injected into a nearly-equatorial orbit around Jupiter with first apoapse at about $270 R_J$. Subsequent orbits will be chosen by powered maneuvers and close fly-bys of the Galilean satellites to optimize the fulfillment of scientific objectives of magnetospheric, satellite, and planetary observations. The nominal mission will terminate in March 1987.

Two of the three University of Iowa proposals for experiments on Galileo have been selected. Formal confirmation proceedings are scheduled for late summer 1978. The two investigations and the primary investigators are as follows:

2.15.1 "A Plasma Wave Investigation for the
1981/1982 Jupiter Orbiter"

D. A. Gurnett, Principal Investigator
(U. of Iowa)
F. L. Scarf, Co-Investigator (TRW)
R. Gendrin, Co-Investigator (CNET)
C. F. Kennel, Co-Investigator (UCLA)
S. D. Shawhan, Co-Investigator
(U. of Iowa)

2.15.2 "Comprehensive Investigations of Jovian
Plasmas with the Jupiter Orbiter Spacecraft
(Jupiter Orbiter Probe 1981/1982 Mission)"

L. A. Frank, Principal Investigator
(U. of Iowa)
F. V. Coroniti, Co-Investigator (UCLA)
V. M. Vasyliunas, Co-Investigator (MPI)

The design and preliminary engineering are in progress.

In addition, Van Allen has been appointed a member of the Project Science Group and chairman of the Magnetosphere Working Group.

(Proposal work supported by ONR and NASA Headquarters)

(Hardware support by JPL/NASA)

2.16 Spacelab and Orbital Flight Test Missions

Two University of Iowa investigations have been selected and confirmed for the early scientific program with the NASA shuttle/spacelab:

2.16.1 "An Ejectable Plasma Diagnostics Package (PDP) for the Spacelab 2 Mission"

(All Investigators from U. of Iowa)

S. D. Shawhan, Principal Investigator
L. A. Frank, Co-Investigator
D. A. Gurnett, Co-Investigator
N. D'Angelo, Co-Investigator

2.16.2 "An Ejectable Plasma Diagnostics Package (PDP) for the Space Shuttle Orbital Flight Test (OFT) Missions"

(Investigators, same as for 2.16.1)

The University of Iowa is engaged in designing and constructing a complete subsatellite including all scientific instrumentation for preliminary flight on the OFT 4 mission, recovery and re-flight on Spacelab 2. On the latter flight it is planned to release the PDP into a close companion orbit with the mother craft. The objectives of these investigations are to determine the electromagnetic and plasma environments of the Spacelab as a basis for

designing future experiments. In both cases the acquisition of in-flight data will extend over a time period of only about ten days. The subsatellite will be powered by storage batteries. The scientific instrumentation will be similar to that on Hawkeye 1.

(Proposal and preliminary design support by ONR and NASA Headquarters)

(Hardware support by Marshall Space Flight Center/NASA)

2.17 Firewheel Project

The Firewheel Project is a joint European-American experiment for the release of barium clouds in the earth's magnetotail at $\approx 15 R_E$ and for the study of the physical effects thereof, including the possible triggering of a geomagnetic substorm. The central planning agency is the Max Planck Institute at Garching, W. Germany. The European launch vehicle Ariane will be used. The University of Iowa will provide one of the subsatellites for observation of the local plasma and magnetic effects produced by the injected barium clouds. It is planned to use spare flight hardware from the Hawkeye 1 program for this low-cost experiment.

[Gurnett et al.]

(Support by ONR)

2.18 Solar Polar Mission (Formerly called Out-of-Ecliptic Mission)

This NASA/ESA mission contemplates a single launch of two instrumented spacecraft which will then be separated for independent flight. Both will be targeted to fly-by Jupiter in such a way that

their subsequent orbits will be in a plane approximately perpendicular to the equatorial plane of the sun. They will be counter-revolving in this plane with one passing over the north pole of the sun as the other passes over the south pole (both at ~ 1 AU) and vice versa as their orbital motions continue. The unique objectives of these missions are to measure the properties of the interplanetary medium at high solar latitudes, to measure the intensity of galactic cosmic rays and the propagation of solar energetic particles, also at high solar latitudes, and to observe the polar caps of the sun.

The mission is proposed by NASA for a FY 1979 start with launch in February 1983; it is undergoing congressional consideration and is not yet approved. Gurnett is a co-investigator on the tentatively selected plasma wave instrument.

2.19 Advisory Work

During 1977, Van Allen served as:

- (a) Chairman of the Arecibo Advisory Board,
- (b) A member of the ad hoc selection committee for experiments on the Solar Polar Mission, and
- (c) A member of the Fachbeirat (Visiting Committee) to the Laboratory for Extraterrestrial Physics/Max Planck Institute, Garching, W. Germany.

He also continued his three-year term as President of the Solar-Planetary Relationships Section of the American Geophysical

Union. Beginning in August 1977 he has been a member of the Project Science Group and chairman of the Magnetosphere Working Group for the Galileo Project. In November 1977, he participated in the Office of Naval Research's "Workshop on Opportunities for Research in Electronic and Solid State Sciences". During November 1977 -- February 1978 he chaired an "Ad Hoc Computer Review Committee" on the computing facilities of the University of Iowa.

3.0 Senior Academic Staff in Space Physics
 [31 December 1977]

<u>Van Allen, James A.</u>	Carver Professor of Physics and Head of Department of Physics and Astronomy
<u>D'Angelo, Nicola</u>	Professor of Physics
<u>Frank, Louis A.</u>	Professor of Physics
<u>Gurnett, Donald A.</u>	Professor of Physics
<u>Shawhan, Stanley D.</u>	Associate Professor of Physics [On Leave 10 January to 14 May 1977]
<u>Goertz, C. K.</u>	Associate Professor of Physics [On Leave 1 July 1977 to 1 January 1978]
<u>Ackerson, Kent L.</u>	Associate Research Scientist [Research Associate]
<u>Craven, John D.</u>	Associate Research Scientist [Research Associate]
<u>Cronyn, Willard M.</u>	Associate Research Scientist [Research Associate]
<u>Yeager, David M.</u>	Associate Research Scientist [Research Associate]
<u>Randall, Bruce A.</u>	Associate Research Scientist [Effective 1 June 1977]
<u>Sentman, Davis D.</u>	Research Investigator [Research Associate]
<u>Thomsen, Michelle F.</u>	Research Investigator [Effective 1 July 1977]
<u>Rickard, James J.</u>	Assistant Research Scientist [Research Associate]
<u>Mitchell, Donald G.</u>	Assistant Research Scientist [Research Associate]

Also in Closely Related Work
(Astronomy and Plasma Physics)

<u>Montgomery, David C.</u>	Professor of Physics [Terminated 1 September 1977]
<u>Knorr, Georg</u>	Professor of Physics
<u>Hershkowitz, Noah</u>	Professor of Physics
<u>Joyce, Glenn R.</u>	Professor of Physics
<u>Neff, John S.</u>	Associate Professor of Astronomy
<u>Fix, John D.</u>	Associate Professor of Astronomy [On Leave 1 September 1977 to 5 June 1978]
<u>Mutel, Robert L.</u>	Assistant Professor of Astronomy

4.0 Senior Engineering and Administrative Staff
[31 December 1977]

<u>Enemark, Donald C.</u>	Adjunct Associate Professor of Physics
<u>Brechwald, Robert L.</u>	Manager, Systems and Programming Services
<u>Rogers, John E.</u>	Senior Engineer
<u>Robertson, Thomas D.</u>	Contracts Administrator
<u>Anderson, Roger R.</u>	Assistant Research Scientist
<u>Owens, Harry</u>	Research Assistant III
<u>Odem, Daniel L.</u>	Engineer IV
<u>Shaw, Robert R.</u>	Engineer IV
<u>Anderson, Roger D.</u>	Engineer III
<u>Baker, Keith R.</u>	Engineer III [Terminated 31 March 1977]
<u>English, Michael</u>	Engineer III
<u>Jagnow, Paul G.</u>	Engineer III [Terminated 31 July 1977]
<u>Kruse, Elwood A.</u>	Engineer III [R and Q]
<u>Remington, Steve L.</u>	Engineer III
<u>Phillips, James R.</u>	Engineer III
<u>Freund, Edmund A.</u>	Supervisor, Technical Services [Departmental Machine Shop]
<u>Robison, Evelyn D.</u>	Project Assistant [Supervisor, Publications]
<u>Williams, Michael R.</u>	Computer Operations Manager [Terminated 30 June 1977]
<u>Huneke, Alan C.</u>	Engineer II

Senior Engineering and Administrative Staff (continued)

<u>France, Richard J.</u>	Senior Programmer Analyst [Terminated 30 June 1977]
<u>Callahan, Timothy J.</u>	Research Assistant II/EPS [Terminated 31 January 1977]
<u>Lee, James A.</u>	Research Assistant II/EPS
<u>Burek, Barbara G.</u>	Research Assistant II/EPS

5.0 Junior Academic Staff in Space Physics [31 December 1977]

All of those listed below are graduate students, engaged in research in space physics.

	<u>Appointment</u>	<u>Principal Research Project</u>
Baumback, Mark M.	Research Assistant	NASA Research: Waves in Plasma
Benson, John M.	Research Assistant	Radio Astronomy
Burek, Barbara G.	Research Assistant	Interplanetary Medium
Chen, Henry Sha-Lin	Research Assistant	Solar Radio Emissions [Terminated 31 July 1977]
Chen, Tsan-Fu	Research Assistant	Magnetic Fields (Hawkeye)
Cook, Bruce	Teaching Assistant	Radio Astronomy
DeCoster, Richard	Research Assistant	Magnetospheric Physics
Gallagher, Dennis	Research Assistant	VLF Radio (IMP-J)
Green, James L.	Research Assistant	VLF Radio (Hawkeye)(IMP-J)
Hodges, Mark W.	Teaching Assistant	Radio Astronomy
Kurth, William S.	Research Assistant	VLF Radio (Hawkeye)
Lee, James A.	Research Assistant	Electrostatic Analyzers
Pesses, Mark E.	Research Assistant	Pioneer 10/11
Phillips, Robert B.	Teaching Assistant	Radio Astronomy
Thomsen, Michelle F.	Research Assistant	Pioneer 10/11 [Promoted 1 July 1977 to Research Investigator]
Weisberg, Joel M.	Research Assistant and Link Foundation Fellow	Radio Astronomy (Arecibo)

6.0 Advanced Degrees Awarded in Space
Physics at U. of Iowa
1 January 1977 -- 31 December 1977

M.S. Degree

NONE

Ph.D. Degree

Richard Joseph DeCoster II (December 1977): "Observations Pertaining to the Dynamics of the Plasma Sheet"

Michelle F. Thomsen (May 1977): "On Determining a Radial Diffusion Coefficient from the Observed Effects of Jupiter's Satellites"

7.0 Research Reports and Publications
in Space Physics
1 January 1977 -- 31 December 1977

- WILLIAM W. L. TAYLOR and ROGER R. ANDERSON
 Explorer 45 Wave Observations During the Large Magnetic
 Storm of August 4-5, 1972
J. Geophys. Res., 82, 55-66, 1977
- L. A. FRANK, K. L. ACKERSON, and D. M. YEAGER
 Observations of Atomic Oxygen (O^+) in the Earth's
 Magnetotail
J. Geophys. Res., 82, 129-134, 1977
- ROGER R. ANDERSON and KAICHI MAEDA
 VLF Emissions Associated with Enhanced Magnetospheric
 Electrons
J. Geophys. Res., 82, 135-146, 1977
- DONALD A. GURNETT and ROGER R. ANDERSON
 Plasma Wave Electric Fields in the Solar Wind:
 Initial Results from Helios 1
J. Geophys. Res., 82, 632-650, 1977
- D. N. BAKER and J. A. VAN ALLEN
 Revised Pioneer 10 Absolute Electron Intensities in
 the Inner Jovian Magnetosphere
J. Geophys. Res., 82, 681-683, 1977
- D. A. GURNETT and L. A. FRANK
 A Region of Intense Plasma Wave Turbulence on Auroral
 Field Lines
J. Geophys. Res., 82, 1031-1050, 1977
- U. S. INAN, T. F. BELL, and R. R. ANDERSON
 Cold Plasma Diagnostics Using Satellite Measurements of
 VLF Signals from Ground Transmitters
J. Geophys. Res., 82, 1167-1176, 1977
- U. S. INAN, T. F. BELL, D. L. CARPENTER, and R. R. ANDERSON
 Explorer 45 and IMP 6 Observations in the Magnetosphere
 of Injected Waves from the Siple Station VLF Transmitter
J. Geophys. Res., 82, 1177-1187, 1977
- P. KINTNER and N. D'ANGELO
 A Transverse Kelvin-Helmholtz Instability in a Magnetized
 Plasma
J. Geophys. Res., 82, 1628-1630, 1977

- JAMES LAUER GREEN, DONALD A. GURNETT, and STANLEY D. SHAWHAN
 The Angular Distribution of Auroral Kilometric Radiation
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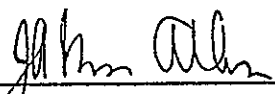
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HAWKEYE 1

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Compiled by:



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2 May 1978

REPORTS AND PUBLICATIONS ON HAWKEYE I
AND RESULTS THEREFROM

BROWN, R. R. (Editor)

Final Report of Hawkeye I Spacecraft
June 1974

VAN ALLEN, J. A.

Hawkeye I: (a) Approximate Determination of Right Ascension and Declination of Spin Axis. (b) Sun Angle as a Function of Time
U. of Iowa Project Memorandum, 24 June 1974

VAN ALLEN, J. A.

Hawkeye I: The Determination of U.T. of Occurrence of Sun Pulses from Telemetered Optical Aspect Data
U. of Iowa Project Memorandum, 6 July 1974

VAN ALLEN, J. A.

Hawkeye I: (a) Third Determination of Right Ascension and Declination of Spin Axis. (b) Sun Angle as a Function of Time
U. of Iowa Project Memorandum, 23 July 1974

VAN ALLEN, J. A., M. N. OLIVEN, and R. A. FLIEHLER

Magnetic Field in the Earth's Polar Magnetosphere to $21 R_E$

EOS, 55, 1167, 1974

SM 6

MAGNETIC FIELD IN THE EARTH'S POLAR MAGNETOSPHERE TO $21 R_E$

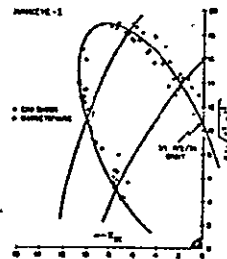
J. A. Van Allen

M. N. Oliven

R. A. Fliehler (all at: Department of Physics and Astronomy, The University of Iowa, Iowa City, Iowa 52242)

The vector magnetic field in the earth's polar magnetosphere is being measured by a Schonstedt three-axis fluxgate magnetometer on Hawkeye I to a radial distance of $21 R_E$ in a plane normal to the earth's equator. Positions of bow shock and magnetopause crossings during the period 3 June -- 21 July 1974 are shown in the figure. During this time period the right ascension of the sun minus that of the descending node of the orbit varied from -47° to $+2^\circ$. The magnetopause occurs at $|B| = 56 (\pm 16) \gamma$, being identified primarily as the transition point between well ordered and disordered fields rather than by

change in the magnitude of B. Bow shocks are usually, but not always, sharply defined (≈ 2 sec) by discontinuities $|\delta B| = 16 (\pm 4) \gamma$. Multiple bow shock crossings are common. A number of magnetic signatures through polar cusps have been observed. The polar magnetosphere was inflated markedly during the period of high geomagnetic activity 4-7 July.



GURNETT, D. A., and W. S. KURTH

Plasma Wave Observations in the Polar Magnetosphere
with Hawkeye 1
EOS, 55, 1175, 1974

SN 74

PLASMA WAVE OBSERVATIONS IN THE POLAR MAGNETOSPHERE WITH HAWKEYE 1

D. A. Gurnett

W. S. Kurth (both at: Department of Physics
and Astronomy, The University of Iowa,
Iowa City, Iowa 52242)

A wide variety of plasma wave phenomena are observed at high altitudes in the polar magnetosphere with the HAWKEYE 1 satellite. Within the polar cusp region electrostatic noise bands are observed at harmonics of the electron cyclotron frequency. Magnetic noise bursts at frequencies below about 100 Hz are also observed near the boundaries of the polar cusp. In the local midnight region broadband whistler mode noise emissions are observed which are qualitatively similar to the VLF auroral hiss frequently detected with low altitude polar orbiting satellites. Broadband bursts of electrostatic noise are also detected at high latitudes in the local evening region. These broadband electrostatic noise bursts are thought to be associated with regions where intense field aligned currents occur. Kilometric radio emissions from the auroral regions are also observed over much of the high latitude, high altitude portions of the orbit. Coordinated measurements with the IMP-6 and IMP-8 satellites show that the kilometric radiation is emitted over a large solid angle (> 3 steradians) with total power levels sometimes exceeding 10^9 watts. Direction finding measurements are being performed to establish the source region of the kilometric radiation.

KURTH, WILLIAM STEVEN

Direction Finding Measurements of Auroral Kilometric Radiation
M.S. Thesis, May 1975

Plasma wave experiments using the rotating dipole antennas of the IMP-8 and HAWKEYE-1 satellites are used to obtain direction finding measurements of auroral kilometric radiation. This radiation is characterized by sporadic storms of very intense radiation lasting from tens of minutes to several hours with the frequency of peak intensity normally lying between 100 kHz and 300 kHz. The noise, which has been associated with bright auroral arcs, causes the earth to appear as a very bright radio source from positions outside the plasmasphere.

HAWKEYE-1 is in a highly elliptical polar orbit with an apogee radial distance of about $21 R_E$ over the northern polar region and IMP-8 is in a slightly eccentric orbit closer to the equatorial plane with perigee and apogee radial distances of 23 and $46 R_E$ respectively. When the source of auroral kilometric radiation lies near the plane in which the electric antennas rotate, the detected signal is strongly spin modulated so that accurate information on the position of the source region can be obtained. A source near the earth often lies near the planes of antenna rotation of both satellites so that two independent determinations of the source location can be made. The results of both determinations agree fairly well and place the source region about $0.9 R_E$ from the polar axis of the earth at a local time of about 20 hours as projected into the equatorial plane. These results support earlier results in that the source must be in the region of the earth's evening auroral zones. The generation mechanism, although still unknown, must then be related to auroral electron precipitation events which are also closely related to bright auroral arcs.

VAN ALLEN, J. A.

Hawkeye I: Projected Sun-Angle 4 June 1974

-- 30 December 1976

U. of Iowa Project Memorandum, 28 May 1975

GREEN, JAMES L., DONALD A. GURNETT, and STANLEY D. SHAWHAN
The Angular Distribution of Auroral Kilometric
Radiation
EOS, 56, 424, 1975

SP 23

THE ANGULAR DISTRIBUTION OF AURORAL KILOMETRIC
RADIATION

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Donald A. Gurnett
Stanley D. Shawhan (all at Department of Physics
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Observations of the angular distribution of
auroral kilometric radiation are made with plas-
ma wave experiments on the HAWKEYE I, IMP-6, and
IMP-8 satellites. HAWKEYE I and IMP-6 provide
information in the narrow frequency bands cent-
ered at 178 kHz, 100 kHz, and 56.2 kHz with an
additional coverage by IMP-8 at 2 Mhz and 500
kHz. All three satellites show the auroral

kilometric radiation occurring in sporadic
bursts or storms whose duration varies from half
an hour to several hours. From a frequency of
occurrence survey, at large radial distances,
it appears that kilometric radiation is emitted
into a solid conical pattern over the auroral
zones whose solid angle depends on frequency.
The larger the frequency, the larger the solid
angle. A correlation between the satellites is
also made on the "beam" width of individual
bursts of this electromagnetic radiation. The
beam of the individual burst lies within the
general emission cone. In addition, a computer
ray tracing model for auroral kilometric radia-
tion is discussed. It assumes a small source
located at altitudes of 1.0 to 3.0 R_E in the
auroral zone. The model predicts the variations
in the solid angle of the emission cone as a
function of frequency which are observed experi-
mentally.

KINTNER, P. M., D. A. GURNETT, K. L. ACKERSON, and L. A. FRANK
Correlated Electric Field, Plasma Wave, and Particle
Measurements from the Hawkeye 1 Satellite
EOS, 56, 433, 1975

SP 96

CORRELATED ELECTRIC FIELD, PLASMA WAVE, AND
PARTICLE MEASUREMENTS FROM THE HAWKEYE 1
SATELLITE

P. M. Kintner
D. A. Gurnett
K. L. Ackerson
L. A. Frank (all at Department of Physics and
Astronomy, University of Iowa, Iowa City,
Iowa 52242)

The HAWKEYE 1 satellite carries a 43 meter cy-
lindrical boom system from which electric field
measurements can be made at low altitudes. As
HAWKEYE is in a highly elliptical orbit with
perigee over the south pole, reliable electric
fields are observed over the south polar cap in-
cluding electric field reversals indicative of
the transition from open to closed magnetic field
lines. On the dayside the reversal is near but
not coincident with the 45 keV trapping boundary
nor the cusp which is inferred from soft electron
measurements. Within the cusp and field reversal,
VLF hiss is observed as well as a noise band below
the ion cyclotron frequency.

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FRANK, L. A., K. L. ACKERSON, J. D. CRAVEN, and J. A. VAN ALLEN
 Plasma Convection in the Magnetotail and Polar
 Magnetosphere
EOS, 56, 433, 1975

SP 104

PLASMA CONVECTION IN THE MAGNETOTAIL
 AND POLAR MAGNETOSPHERE

L. A. Frank
 K. L. Ackerson
 J. D. Craven
 J. A. Van Allen (all at: Department of
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Observations of plasmas to geocentric radial distances of $20 R_E$ have been gained in the earth's polar magnetosphere with LEPEDEA instrumentation flown on the Hawkeye-1 satellite. Simultaneous measurements of plasmas in the plasma sheet of the magnetotail at radial distances $> 30 R_E$ are available from similar instrumentation on the IMP-7 and -8 satellites. Two major realms of plasma convection in the polar magnetosphere have been identified thus far in our analyses: (1) plasma flows directed parallel or antiparallel to the local magnetic field within the polar cusp and the plasma mantle and (2) plasma flows characterized by considerably higher densities, which are directed obliquely to the local magnetic field vector. Both ion flows, \sim hundreds of $\text{km}(\text{sec})^{-1}$, are observed for extended periods, \sim hours. In the distant magnetotail similar convection of plasma accompanies magnetic substorms. An example of these plasma flows with simultaneous measurements in the magnetotail and the polar magnetosphere during a magnetic substorm is to be presented.

KURTH, W. S., M. M. BAUMBACK, and D. A. GURNETT
 Direction-Finding Measurements of Auroral Kilometric
 Radiation
J. Geophys. Res., 80, 2764-2770, 1975

Direction-finding measurements with plasma wave experiments on the Hawkeye 1 and Imp 8 satellites are used to locate the source region of auroral kilometric radiation. This radiation has peak intensities between about 100 and 300 kHz and is emitted in intense sporadic bursts lasting for from half an hour to several hours. At peak intensity the total power emitted in this frequency range exceeds 10^6 W. The occurrence of this radiation is known to be closely associated with bright auroral arcs which occur in the local evening auroral regions. Hawkeye 1 provides direction-finding measurements of kilometric radiation from observations at high latitudes ($5-20 R_E$) over the northern polar regions, and Imp 8 provides similar observations at large radial distances ($23-46 R_E$) near the equatorial plane. Results from both satellites place the source of the intense auroral kilometric radiation in the late local evening at about 22.0 hours LT and at a distance of about $0.75 R_E$ from the polar axis of the earth. These direction-finding measurements, together with earlier results from the Imp 6 satellite, strongly indicate that the intense auroral kilometric radiation is generated by energetic auroral electrons at low altitudes in the evening auroral zone. The observed source location is in good quantitative agreement with the source position expected from simple propagation and ray path considerations.

VAN ALLEN, J. A.

Hawkeye I: Assessment of Prospects for Obtaining Interplanetary Magnetic Field Data with Hawkeye I During the Los Alamos Rocket Operation at Cape Perry, 24 November -- 6 December 1975
U. of Iowa Project Memorandum, 7 November 1975

SAFLEKOS, N. A.

Hawkeye I Spin Axis Orientation as Deduced from Magnetometer Measurements, 14 June 1974
-- 17 September 1975
U. of Iowa Project Memorandum, 16 December 1975

KINTNER, P. M.

A Low Frequency Electromagnetic Noise Band Related to Bulk Plasma Convection
EOS, 56, 1033, 1975

SA 39

A LOW FREQUENCY ELECTROMAGNETIC NOISE BAND RELATED TO BULK PLASMA CONVECTION

P. M. Kintner (Dept. of Physics and Astronomy, The University of Iowa, Iowa City, IA 52242)

HAWKEYE 1 is in a highly elliptical orbit with perigee over the south polar cusp at 2000 km. Between 2000 and 4000 km altitude an electromagnetic noise band is observed in the four lowest frequency filters, 1.7 Hz through 56 Hz, while the satellite is traversing auroral field lines.

Maximum power in the 1.7 Hz electric channel exceeds 10^{-6} volt²/m²-Hz. The index of refraction, $n=B/E$, is found to be approximately 200 during the noise emissions. Bulk plasma convection measurements are also made on HAWKEYE with a static electric field meter. By noting the change in convection velocity with respect to satellite position the quantity dV/dx is calculated where the distance x is nearly perpendicular to the local magnetic field. The spatial shear in convection velocity is found to be coincident with the low frequency electromagnetic noise band which suggests the noise band is generated by the Kelvin-Helmholtz instability.

ACKERSON, K. L., and L. A. FRANK

Plasma Flow Velocities at the Dayside Magnetopause -- at Low Latitudes with IMP-6 and at High Latitudes with Hawkeye
EOS, 56, 1050, 1975

SM 64

PLASMA FLOW VELOCITIES AT THE DAYSIDE MAGNETOPAUSE--AT LOW LATITUDES WITH IMP-6 AND AT HIGH LATITUDES WITH HAWKEYE

K. L. Ackerson

L. A. Frank (both at: Department of Physics and Astronomy, University of Iowa, Iowa City, Iowa 52242)

Plasma flows at the dayside magnetopause near the magnetic equatorial plane have been obtained via LEFEDEA instrumentation on board IMP-6. The spin axis of the spacecraft is directed nearly

perpendicular to the ecliptic plane; hence the component of plasma flow which is measured lies parallel to the ecliptic. Jetting of plasma near the magnetopause and a reversal of plasma flows at the magnetopause are observed in several examples. The polar-orbiting Hawkeye is also employed to determine plasma flows at the magnetopause--but at high latitudes near the polar cusp and in a plane nearly perpendicular to the ecliptic. The character of plasma distributions at these high latitudes is relatively complex.

SAFLEKOS, N. A.

Hawkeye I Spin Axis Orientation Deduced from the Magnetometer for the First 470 Days Since Launch
U. of Iowa Project Memorandum, 31 March 1976

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Direction-Finding Measurements of Type III Radio Bursts
Out of the Ecliptic Plane
M.S. Thesis, May 1976

Direction-finding measurements with the plasma wave experiments on the HAWKEYE 1 and IMP 8 satellites are used to find the interplanetary source locations of type III solar radio bursts in heliocentric latitude and longitude in a frequency range from 31.1 kHz to 500 kHz. Three events in the period from June 1974 to August 1974 were suitable to analyze completely. IMP 8 has its spin axis perpendicular to the ecliptic plane; hence, by analyzing the spin modulation of the received signals the location of the type III burst projected into the ecliptic plane can be found. HAWKEYE 1 has its spin axis nearly parallel to the ecliptic plane; hence, the location of the source out of the ecliptic plane can also be determined. Using an empirical model for the emission frequency as a function of radial distance from the sun the three-dimensional trajectory of the type III radio source can be determined from direction-finding measurements at difference frequencies. If the electrons which produce these radio emissions are assumed to follow the magnetic field lines from the sun these measurements provide information on the three-dimensional structure of the magnetic field in the solar wind. The source locations projected into the ecliptic plane were found to follow an Archimedean spiral. Perpendicular to the ecliptic plane the source locations were found to usually follow a constant heliocentric latitude. When the best fit magnetic field line through the source locations is extrapolated back to the sun this field line usually originates within a few degrees from the solar flare which produced the radio burst. With direction-finding measurements of this type it is also possible to determine the source size from the modulation factor of the received signals. For a type III event on June 8, 1974, the half angle source size was measured to be $\sim 60^\circ$ at 500 kHz and $\sim 40^\circ$ at 56.2 kHz as viewed from the sun.

GREEN, JAMES L.

The Angular Distribution of Auroral Kilometric Radiation
M.S. Thesis, May 1976

Observations of the angular distribution of auroral kilometric radiation (AKR) are made with plasma wave experiments on the HAWKEYE-1, IMP-6, and IMP-8 satellites. The wave experiments on these satellites use a long dipole antenna for electric field measurements in narrow frequency bands centered at 178, 100, and 56.2 kHz with additional data from IMP-8 at 500 kHz. All three satellites observe auroral kilometric radiation occurring in sporadic bursts or storms lasting from half an hour to several hours. From a frequency of occurrence survey, at satellite radial distances greater than $7 R_E$ (earth radii), it appears that AKR is preferentially and instantaneously being beamed into solid angles of approximately 3.5 steradians at 178 kHz, 1.8 steradians at 100 kHz, and 1.1 steradians at 56.2 kHz from the auroral zones.

From simultaneous multiple satellite observations of auroral kilometric radiation it is noted that the plasmapause acts as an abrupt low latitude propagation cutoff on the night side of the earth. On the day side, however, this abrupt cutoff at the plasmapause is not observed.

A computer ray tracing model describing the propagation of auroral kilometric radiation is developed. This model assumes a small source location at altitudes of 1.0 to 3.0 R_E in the auroral zone at 24 hours magnetic local time. The ray tracing results agree qualitatively with the observed variations in the solid angle of the emission cone as a function of frequency assuming that the radiation is emitted at $3/2$ times the electron gyrofrequency.

BAUMBACK, M. M., W. S. KURTH, and D. A. GURNETT

Direction-Finding Measurements of Type III Radio Bursts
Out of the Ecliptic Plane
Solar Physics, 48, 361-380, 1976

Abstract. Direction-finding measurements with the plasma wave experiments on the HAWKEYE 1 and IMP 8 satellites are used to find the source locations of type III solar radio bursts in heliocentric latitude and longitude in a frequency range from 31.1 kHz to 500 kHz. IMP 8 has its spin axis perpendicular to the ecliptic plane; hence, by analyzing the spin modulation of the received signals the location of the type III burst projected into the ecliptic plane can be found. HAWKEYE 1 has its spin axis nearly parallel to the ecliptic plane; hence, the location of the source out of the ecliptic plane may also be determined. Using an empirical model for the emission frequency as a function of radial distance from the sun the three-dimensional trajectory of the type III radio source can be determined from direction-finding measurements at different frequencies. Since the electrons which produce these radio emissions follow the magnetic field lines from the Sun these measurements provide information on the three-dimensional structure of the magnetic field in the solar wind. The source locations projected into the ecliptic plane follow an Archimedean spiral. Perpendicular to the ecliptic plane the source locations usually follow a constant heliocentric latitude. When the best fit magnetic field line through the source locations is extrapolated back to the Sun this field line usually originates within a few degrees from the solar flare which produced the radio burst. With direction-finding measurements of this type it is also possible to determine the source size from the modulation factor of the received signals. For a type III event on June 8, 1974, the half angle source size was measured to be $\sim 60^\circ$ at 500 kHz and $\sim 40^\circ$ at 56.2 kHz as viewed from the Sun.

GURNETT, D. A.

Plasma Wave Interactions with Energetic Ions Near the
Magnetic Equator
J. Geophys. Res., 81, 2765-2770, 1976

An intense band of electromagnetic noise is frequently observed near the magnetic equatorial plane at radial distance from about 2 to 5 R_E . Recent wide band wave form measurements with the Imp 6 and Hawkeye 1 satellites have shown that the equatorial noise consists of a complex superposition of many harmonically spaced lines. Several distinctly different frequency spacings are often evident in the same spectrum. The frequency spacing typically ranges from a few hertz to a few tens of hertz. The purpose of this paper is to suggest that these waves are interacting with energetic protons, alpha particles, and other heavy ions trapped near the magnetic equator. The possible role that these waves play in controlling the distribution of the energetic ions is considered.

GURNETT, D. A., and L. A. FRANK

Continuum Radiation from Low-Energy Electrons in the
Outer Radiation Zone
J. Geophys. Res., 81, 3875-3885, 1976

A weak nonthermal continuum radiation is generated by the earth's magnetosphere in the frequency range from about 500 Hz to greater than 100 kHz. During magnetically disturbed periods the intensity of this continuum radiation increases significantly, by as much as 20 dB during large disturbances. In this paper we present a series of observations obtained by the Hawkeye 1 and Imp 8 spacecraft during a period of greatly enhanced continuum radiation intensity which occurred from October 14-21, 1974. The enhanced continuum radiation intensities observed during this event are found to be closely correlated with the injection of very intense fluxes of energetic, ~ 1 -30 keV, electrons into the outer radiation zone. Direction-finding measurements of the continuum radiation observed during this event show that the radiation is primarily coming from the dawn side of the magnetosphere, in agreement with the observed dawn-dusk asymmetry in the 1- to 30-keV electron distribution. These results suggest that the continuum radiation may be generated by a coherent plasma instability involving relatively low-energy, ~ 1 to 30 keV, electrons rather than by gyrosynchrotron radiation from very energetic, 200 keV to 1 MeV, electrons as has been previously suggested.

KINTNER, P. M., JR.

Observations of Velocity Shear Driven Plasma Turbulence
J. Geophys. Res., 81, 5114-5122, 1976

Electrostatic and magnetic turbulence observations from Hawkeye 1 during the low-altitude portion of its elliptical orbit over the southern hemisphere are presented. The magnetic turbulence is confined near the auroral zone and is similar to that seen at higher altitudes by Heos 2 in the polar cusp. The electrostatic turbulence is composed of a background component with a power spectral index of 1.89 ± 0.26 and an intense component with a power spectral index of 2.80 ± 0.34 . The intense electrostatic turbulence and the magnetic turbulence correlate with velocity shears in the convective plasma flow. Since velocity shear instabilities are most unstable to wave vectors perpendicular to the magnetic field, the shear correlated turbulence is anticipated to be two-dimensional in character and to have a power spectral index of 3, which agrees with that observed in the intense electrostatic turbulence.

GURNETT, D. A.

The Earth as a Radio Source
Magnetospheric Particles and Fields
 Ed. B. M. McCormac, pp. 197-208, 1976

Abstract. Satellite low frequency radio measurements have revealed that the Earth is a very intense and interesting radio source with characteristics similar to other astronomical radio sources such as Jupiter, Saturn and the Sun. In this paper we summarize the primary characteristics of radio emissions from the Earth's magnetosphere, consider the origin of these emissions, and discuss the similarities to other astronomical radio sources.

GURNETT, D. A.

Electrostatic Turbulence in the Magnetosphere
Physics of Solar Planetary Environments, Vol. II,
 Ed. D. J. Williams, pp. 760-771, 1976

Plasma wave measurements from the IMP-6, IMP-8 and Hawkeye-1 satellites show that a broad region of intense low-frequency electric field turbulence occurs on the high latitude auroral field lines at altitudes ranging from a few thousand kilometers in the ionosphere to many earth radii in the distant magnetosphere. A qualitatively similar, but less intense, type of electric field turbulence is also observed at the plasmapause during magnetic storms. In the auroral regions the turbulence occurs in an essentially continuous band on the auroral L-shells at all local times around the earth and is most intense during periods of auroral activity. In this paper we summarize the basic characteristics of this electric field turbulence and consider the possible role this turbulence may play in the heating and acceleration of plasma in the magnetosphere.

ABRAHAM, D. W.

Determination of Spin Indices for Hawkeye I from
 Magnetometer and LEPEDea Data
 U. of Iowa Project Memorandum, Draft December 1976

GURNETT, D. A., L. A. FRANK, and R. P. LEPPING
Plasma Waves in the Distant Magnetotail
J. Geophys. Res., 81, 6059-6071, 1976

In this study we identify the principal types of plasma waves which occur in the distant magnetotail, and we investigate the relationship of these waves to simultaneous plasma and magnetic field measurements made on the same spacecraft. The observations used in this study are from the Imp 8 spacecraft, which passes through the magnetotail at radial distances ranging from about 23.1 to 46.3 R_E . Three principal types of plasma waves are detected by Imp 8 in the distant magnetotail: broad band electrostatic noise, whistler mode magnetic noise bursts, and electrostatic electron cyclotron waves. The electrostatic noise is a broad band emission which occurs in the frequency range from about 10 Hz to a few kilohertz and is the most intense and frequently occurring type of plasma wave detected in the distant magnetotail. This noise is found in regions with large gradients in the magnetic field near the outer boundaries of the plasma sheet and in regions with large plasma flow speeds, 10^3 km s⁻¹, directed either toward or away from the earth. The whistler mode magnetic bursts observed by Imp 8 consist of nearly monochromatic tones which last from a few seconds to a few tens of seconds. These noise bursts occur in the same region as the broad band electrostatic noise, although much less frequently, and are thought to be associated with regions carrying substantial field-aligned currents. Electrostatic electron cyclotron waves are seldom detected by Imp 8 in the distant magnetotail. Although these waves occur very infrequently, they may be of considerable importance, since they have been observed in regions near the neutral sheet when the plasma is extremely hot.

CRAVEN, J. D., K. L. ACKERSON, and L. A. FRANK
Plasma Observations in the Distant Polar Cusp with
Hawkeye 1
EOS, 57, 989, 1976

54 48

PLASMA OBSERVATIONS IN THE DISTANT
POLAR CUSP WITH HAWKEYE 1

J. D. Craven
K. L. Ackerson
L. A. Frank (all at: Dept. of Physics
and Astronomy, University of Iowa,
Iowa City, Iowa 52242)

Plasmas within the distant polar cusp at altitudes $> 5R_E$ have been surveyed with the highly eccentric, polar-orbiting satellite Hawkeye 1 near the local-noon meridional plane. The satellite apogee and perigee altitudes were 127,000 km and 500 km, respectively; the orbital inclination was 89.8° and period 51.3 hours. Directional, differential intensities of ions and electrons over the energy range extending from 30 eV to 50 keV were gained

with an electrostatic analyzer, a IEPEDA. The instrumental fields-of-view were directed perpendicular to the satellite spin axis. For the period of present analyses, this spin axis was aligned nearly parallel to the earth-sun vector. Hence components of bulk flows in a plane nearly parallel to the YSM - ZSM plane are measured. We report ion bulk speeds of several hundreds of km(sec)⁻¹ with components directed dominantly in the +YSM-direction at 1200-1400 h MLT within the polar cusp. These flows were observed to remain steady, to within $\pm 30^\circ$, throughout transits into the polar cusp bounded by the magnetosheath at high altitudes and the outer radiation zone at lower altitudes. Plasma flows are shown for a variety of geomagnetic conditions.

VAN ALLEN, J. A. (Editor)
Hawkeye I: University of Iowa
U. of Iowa Research Report 77-6

ROGERS, JOHN E. (Editor)
Hawkeye 1/Neutral Point Explorer
(Explorer 52/1974-040A)
Final Report of Spacecraft Control Operations,
Telemetry Station Operations, and Data Reduction
U. of Iowa Research Report 77-14

GURNETT, D. A., and L. A. FRANK

A Region of Intense Plasma Wave Turbulence on Auroral Field Lines

J. Geophys. Res., 82, 1031-1050, 1977

Plasma wave measurements from the Hawkeye 1 and Imp 6 satellites show that a broad region of intense plasma wave turbulence occurs on the high-latitude auroral field lines at altitudes ranging from a few thousand kilometers in the ionosphere to many earth radii in the distant magnetosphere. This turbulence occurs in an essentially continuous band on the auroral L shells at all local times around the earth and is most intense during periods of auroral activity. The electric field intensity of this turbulence is often quite large, with maximum field strengths of about 10 mV m^{-1} and peak intensities in the frequency range 10-50 Hz. Magnetic field perturbations indicative of field-aligned currents and weak bursts of whistler mode magnetic noise are also observed in the same region as the electric field turbulence. In the local afternoon and evening the electric field turbulence is closely associated with V-shaped auroral hiss emissions. In some cases the electric field turbulence appears as a lowering and intensification of the low-frequency portion of the auroral hiss spectrum. Comparisons with plasma measurements and with similar measurements from other satellites strongly suggest that this plasma wave turbulence occurs on magnetic field lines which connect with regions of intense inverted V electron precipitation at low altitudes and with regions of intense earthward plasma flow in the distant magnetotail. The plasma instabilities which could produce this turbulence and the possible role which this turbulence may play in the heating and acceleration of the auroral particles are considered.

KINTNER, P., and N. D'ANGELO

A Transverse Kelvin-Helmholtz Instability in a Magnetized Plasma

J. Geophys. Res., 82, 1628-1630, 1977

For a low- β plasma the growth of low-frequency waves is analyzed when the plasma flow transverse to the magnetic field is sheared ($\nabla \cdot \mathbf{E} \neq 0$). A comparison is made with recent observations by Kelley and Carlson (1976) of electrostatic turbulence in the vicinity of auroral arcs.

GREEN, J. L., D. A. GURNETT, and S. D. SHAWHAN

The Angular Distribution of Auroral Kilometric Radiation

J. Geophys. Res., 82, 1825-1838, 1977

Measurements of the angular distribution of auroral kilometric radiation (AKR) are presented by using observations from the Hawkeye 1, Imp 6, and Imp 8 satellites. The University of Iowa plasma wave experiments on Hawkeye 1 and Imp 6 provide electric field measurements of AKR in narrow frequency bands centered at 178, 100, and 56.2 kHz, and the Imp 8 experiment provides measurements at 500 kHz. From a frequency of occurrence survey, at radial distances greater than $7 R_E$ (earth radii) it is shown that AKR is preferentially and instantaneously beamed into solid angles of approximately 3.5 sr at 178 kHz, 1.8 sr at 100 kHz, and 1.1 sr at 56.2 kHz, directed upward from the nighttime auroral zones. Simultaneous multiple satellite observations of AKR in the northern hemisphere show that the radiation occurs simultaneously throughout these solid angles and that the plasmapause acts as an abrupt propagation cutoff on the nightside of the earth. No comparable cutoff is observed at the plasmapause on the dayside of the earth.

The results of computer ray tracing calculations for both the right-hand ($R-X$) and left-hand ($L-O$) polarized modes are also presented in an attempt to understand the propagation characteristics of the AKR. These calculations assume that a small source emits radiation at various frequencies along a magnetic field line at 70° invariant latitude near local midnight. The approximate altitude of the source can be determined for each of the two modes of propagation by adjusting the source altitude to give the best fit to the observed angular distributions. The $R-X$ mode is found to give the best agreement with the observed angular distributions.

VOOTS, G. R., and D. A. GURNETT
Auroral Kilometric Radiation as an Indicator of
Auroral Magnetic Disturbances
J. Geophys. Res., 82, 2259-2266, 1977

Satellite low-frequency radio measurements have shown that an intense radio emission from the earth's auroral regions called auroral kilometric radiation is closely associated with auroral and magnetic disturbances. In this paper we present a detailed investigation of this relationship, using the auroral electrojet (AE) index as an indicator of auroral magnetic disturbances and radio measurements from the Imp 6 spacecraft. This study indicates that the mean power flux of the 178-kHz radiation tends to be proportional to $(AE)^{1/2}$ for $AE > 100 \gamma$ and, with less certainty, to $(AE)^2$ for $AE < 100 \gamma$. The correlation coefficient between $\log AE$ and the logarithm of the power flux is 0.514. Occasionally, a kilometric radiation event is detected which is not detected by the ground magnetometer stations, even though an auroral substorm is in progress. This study shows that the remote detection of kilometric radio emissions from the earth can be used as a reasonably reliable indicator of auroral substorm activity.

KINTNER, PAUL M., and DONALD A. GURNETT
Observations of Ion Cyclotron Waves Within the Plasmasphere
by Hawkeye 1
J. Geophys. Res., 82, 2314-2318, 1977

A survey of the plasma wave data from the Hawkeye 1 spacecraft has been performed in search of ion cyclotron waves associated with the scattering and loss of ring current ions within and near the plasma-pause. During an 18-month period, consisting of about 270 orbits, a total of five events have been found with clearly detectable electric and magnetic fields at frequencies below the proton gyrofrequency. Comparisons of the electric and magnetic field amplitudes for these events provide strong evidence that these waves are ion cyclotron waves. All five events occurred during recovery phases of magnetic storms inside or very close to the plasmapause boundary. The results of this survey confirm and are consistent with the earlier identification of ion cyclotron waves by the Explorer 45 satellites. The Hawkeye 1 observations show that ion cyclotron waves of substantial amplitude occur at magnetic latitudes well away ($\sim 28^\circ$) from the magnetic equator.

GREEN, JAMES LAUER, and DONALD A. GURNETT
A Determination of the Polarization of Terrestrial
Kilometric Radiation
EOS, 58, 467-468, 1977

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A DETERMINATION OF THE POLARIZATION OF TERRESTRIAL KILOMETRIC RADIATION

James Lauer Green
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52242)

Observations of terrestrial kilometric radiation by the Hawkeye-1 spacecraft from low-altitude passes over the southern hemisphere have now provided a determination of the polarization of this radiation. The technique used is to compare observed cutoffs in the radio emission spectrum with the local characteristic frequencies of the plasma as the spacecraft passes through the polar ionosphere at radial distances ranging from about 1.5 to 2.5 R_E . Usually two distinct components can be detected in the radio emission spectrum, (1) a relatively weak continuum component extending from frequencies greater than 178 kHz down to the local electron plasma frequency, f_p , and (2) a very intense sporadic component, called auroral kilometric radiation (AKR), which has a low-frequency cutoff at the local electron gyrofrequency, f_g . Since f_p is usually much less than f_g in the region where these observations were obtained, the cutoff at f_g corresponds to the propagation cutoff of the right-hand polarized

mode of propagation. This cutoff therefore uniquely identifies the polarization of the AKR as right-hand. Since the continuum radiation usually extends downward to frequencies substantially below f_p , this radiation must be at least partially left-hand polarized, since the right-hand mode cannot propagate at frequencies less than f_p . Spatial surveys show that the continuum radiation is observed at nearly all local times over the polar region, whereas the intense AKR is mainly detectable on the evening and night side of the earth. The polarization and spatial distribution of both types of noise are found to be in good agreement with various ray tracing models.

KURTH, W. S., and D. A. GURNETT
 Intense Electrostatic Waves in the Earth's Magnetosphere
 Near the Electron Plasma Frequency
EOS, 58, 469, 1977

54 13

INTENSE ELECTROSTATIC WAVES IN THE EARTH'S
 MAGNETOSPHERE NEAR THE ELECTRON PLASMA FRE-
 QUENCY

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A search for very intense ($> 1 \text{ mV m}^{-1}$) elec-
 trostatic waves in the earth's magnetosphere is
 undertaken using a search of five and one-half
 years of plasma wave observations taken from
 the IMP 6 and Hawkeye 1 satellites. Intense
 electrostatic waves are required by various
 theories to produce intense electromagnetic
 waves such as auroral kilometric radiation.
 This study shows little evidence of electro-
 static waves with intensities greater than 1 mV
 m^{-1} on the auroral field lines.

A small number of intense electrostatic wave
 events are found in a region approximately 2 to
 $8 R_E$ from the earth at magnetic latitudes less
 than 40° . One class of events occurs between 5
 and 20 kHz and is found at all local times, but
 primarily in the morning hemisphere. These low
 frequency electrostatic waves are generally
 found between 4 and $8 R_E$. A second class of
 events appears to be associated with the upper
 hybrid resonance frequency and consists of
 waves at frequencies greater than 10 kHz.
 These higher frequency electrostatic waves are
 usually found between 2 and $6 R_E$ from the earth
 in the morning hemisphere. In many cases in-
 tense electrostatic waves at the upper hybrid
 resonance coincide with intense continuum
 radiation, suggesting that the electrostatic
 waves may be involved in the generation of the
 continuum radiation.

CRAVEN, J. D., and L. A. FRANK
 Some Observed Properties of Plasmas Found in the Polar Cusp
EOS, 58, 472, 1977

54 38

SOME OBSERVED PROPERTIES OF PLASMAS
 FOUND IN THE POLAR CUSP

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A highly eccentric polar orbit extend-
 ing to apogee altitudes of 127,000 km
 provides the Hawkeye 1 satellite with
 regular access to the distant polar
 magnetosphere and adjacent regions of
 the magnetosheath, wherein the local
 plasmas are surveyed with LEPDEA plasma
 instrumentation over an energy range
 30 eV to 40 keV. Properties of these
 plasmas are determined by computing from
 the measured directional, differential
 intensities best-fit analytic expres-
 sions for the velocity distribution
 functions, $n(\vec{v})$, through the method of
 least squares, and by evaluating moments
 of $n(\vec{v})$. Plasma bulk flow velocities
 projected onto the satellite spin plane,
 particle number densities and mean ener-
 gies, and the orientations of anisotrop-
 ies in $n(\vec{v})$ relative to the flow direc-
 tions and magnetic vector orientations
 are of principal initial interest. For
 observations gained near the local-noon
 meridional plane, the satellite spin
 plane is approximately coincident with
 the solar magnetospheric Y-Z plane.
 Within the polar-cusp-like region of
 reduced magnetic energy density, and as
 the magnetic vector rotates from direc-
 tions favored within the magnetosheath
 to more dipolar orientations, the pro-
 jected plasma flow vector can be observed
 to reorientate from directions typical of
 flows within the magnetosheath towards
 more earthward directions.

GURNETT, D. A., and L. A. FRANK
Plasma Wave Turbulence of Auroral Field Lines:
Near Earth Results
EOS, 58, 476, 1977

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PLASMA WAVE TURBULENCE ON AURORAL FIELD
LINES: NEAR EARTH RESULTS

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52242)

Previous studies with the Hawkeye 1, IMP 6 and IMP 8 spacecraft have revealed a region of intense low-frequency electrostatic and whistler-mode turbulence which extends along the auroral field lines from low altitudes in the ionosphere to many earth radii in the distant magnetosphere. Because of limitations in the orbital coverage our previous investigations of this turbulence did not include the very important radial distance range from about 1.8 to 4.0 R_E , within which the primary auroral acceleration is thought to occur. However, data obtained from the Hawkeye 1 spacecraft over the southern polar regions during the last year

have now extended the orbital coverage to include this region. The spectral characteristics of the plasma wave turbulence in this region are similar to the previous results at higher altitudes, consisting of (1) a broad band of electrostatic noise with peak intensities from about 10 to 50 Hz and (2) brief bursts of magnetic noise from below 1 Hz to several hundred Hz. The primary new result is that the electric field strength of the broadband electrostatic noise is considerably larger in the radial distance range around 2.0 R_E , frequently exceeding 100 mV m⁻¹. These large turbulent electric fields are always found in regions with large fluxes of low-energy electrons or protons. Electric field spectrums obtained at various points along the auroral field line permit a detailed evaluation of the effects of anomalous resistivity. Using existing equations for the anomalous resistivity the turbulence can account for potential drops of up to 1 kV in regions of field-aligned currents associated with the auroral electron precipitation.

GREEN, JAMES LAUER and DONALD A. GURNETT
A Determination of the Polarization of Terrestrial
Kilometric Radiation
Third General Assembly of the International Association
of Geomagnetism and Aeronomy, Seattle, WA
(22 August -- 3 September 1977)

A DETERMINATION OF THE POLARIZATION OF
TERRESTRIAL KILOMETRIC RADIATION

James Lauer Green (Dept. of Physics and Astron.,
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Donald A. Gurnett (Dept. of Physics and Astron.,
Univ. of Iowa, Iowa City, IA 52242, USA)

Indirect polarization measurements of terrestrial kilometric radiation can be made from the University of Iowa plasma wave experiment and fluxgate magnetometer on board the Hawkeye I spacecraft during low altitude (1.5 to 2.5 R_E) passes over the southern hemisphere. The method used is to compare observed cutoffs in the radio emission spectrum with the local characteristic frequencies of the plasma. Usually what is observed in the radio emission spectrum near 178 kHz are an intense and sporadic component called auroral kilometric radiation (AKR) and a relatively weak continuum component. AKR is observed to have a low frequency cutoff at the local electron gyrofrequency, f_g^- , while the continuum radiation usually extends downward to frequencies substantially below f_g^- to the electron plasma frequency, f_p^- . In the region where these observations were made, a

cutoff at f_{ce}^- would correspond closely to the propagation cutoff of the R-X mode. In addition, any radiation seen above and below f_{ce}^- must be propagating in the L-O mode. This implies that AKR is strongly right-hand polarized and the weak continuum is at least partially left-hand polarized. From an analysis of the spin modulation of the continuum component it is determined that the electric field vector of this radiation lies nearly in the same plane as the local magnetic field vector. Spatial surveys reveal that continuum radiation is observed at nearly all local times over the south polar region but AKR is observed entirely on the night side of the earth from 18 to 4 hours local time. The polarization and spatial distribution of both types of noise are found to be in good agreement with various ray tracing models. Knowledge of the polarization will aid theorists in determining the generation mechanisms for these two types of radiation.

GURNETT, DONALD A.

Observations of Electromagnetic Waves on Auroral Field Lines

Third General Assembly of the International Association of Geomagnetism and Aeronomy, Seattle, WA
(22 August -- 3 September 1977)

OBSERVATIONS OF ELECTROMAGNETIC WAVES ON AURORAL FIELD LINES

Donald A. Gurnett (Dept. of Physics and Astronomy,
Univ. of Iowa, Iowa City, IA 52242, USA)

Several types of electromagnetic waves are known to be emitted by charged particles on the auroral field lines. In this paper we review the most important types of auroral radio emissions, both from a historical perspective as well as from the standpoint of the latest results. Particular emphasis is placed on three types of electromagnetic emissions which are directly associated with the plasma on the auroral field lines. These emissions are (1) auroral kilometric radiation, which is an extremely intense radio emission generated at frequencies above the local electron plasma frequency, usually from about 100 to 500 kHz, (2) auroral hiss, which is a broad-band whistler-mode emission generated at frequencies below the electron gyrofrequency, usually from about 1 to 30 kHz, and (3) ELF noise bands, which consist of many discrete narrow-band emissions, comparable to the electro-magnetic turbulence commonly observed in the magnetosheath and polar cusp, at frequencies below a few hundred Hz. Strong evidence based on ray tracing and radio direction finding measurements now indicates that both the auroral kilometric radiation and the auroral hiss emissions are generated along the auroral field lines relatively close to the earth, at radial distances

from about 2.5 to 5 R_E , probably in direct association with the acceleration of auroral particles by parallel electric fields. The exact mechanism by which these radio emissions are generated has not been firmly established. For the auroral hiss the favored mechanism appears to be amplified Cerenkov radiation. For the auroral kilometric radiation several mechanisms have been proposed, all involving the intermediate generation of electrostatic waves by the precipitating electrons.

CRAVEN, J. D., and L. A. FRANK
Observations of Plasmas in the Polar Magnetosphere
with Hawkeye 1
EOS, 58, 1207, 1977

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OBSERVATIONS OF PLASMAS IN THE
POLAR MAGNETOSPHERE WITH HAWKEYE 1

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Further new observations of plasmas found at high latitudes and at radial distances in excess of 4 R_E are providing additional information on the spatial distributions of the several plasma regimes operative in the polar magnetosphere. These observations within the high-latitude magnetosheath, entry layer, plasma mantle, and polar cusp are obtained with plasma instrumentation on board the University of Iowa satellite Hawkeye 1. Special initial interest has been directed towards measurements gained when the satellite orbit lies near the noon-midnight meridional plane and the trajectory is most favorably positioned to intercept the polar cusp. During these periods the satellite spin plane lies nearly parallel to the solar-magnetospheric Y-Z plane. The polar cusp has been detected unambiguously during the summers of 1976 and 1977. In these periods the satellite exited from the high-latitude magnetosheath and plasma mantle and passed through the low-density plasmas of the polar cap prior to traversing the polar cusp. Typical transverse dimensions for the polar cusp at radial distances of 4 to 7 R_E are of the order of several earth radii. This provides sufficient time to obtain the gross properties of plasmas within the polar cusp. The equatorward edge of the polar cusp is well delineated by abrupt increases in the mean energies of protons and electrons.

GREEN, JAMES LAUER, and DONALD A. GURNETT
 Evidence of Strong Coupling Between Auroral Hiss and
 Auroral Kilometric Radiation
EOS, 58, 1214, 1977

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EVIDENCE OF STRONG COUPLING BETWEEN AURORAL
 HISS AND AURORAL KILOMETRIC RADIATION

James Lauer Green

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Except for a few cases, the confinement of the auroral kilometric radiation to frequencies above the local electron gyrofrequency is a general feature of all the HF waves in southern hemisphere observations. These special cases show auroral kilometric radiation at 170 kHz merging essentially continuously into a noise band which extends down to frequencies as low as a few hundred Hz. Identification of this noise band as auroral hiss is based on previously observed characteristics of auroral hiss from low altitude

satellites. All these events occur over the auroral zone in the local evening where it is believed the most intense AKR is generated. Thus the spacecraft may be passing through the source region in these cases. Because of the observed continuity in the signal of auroral kilometric radiation and auroral hiss it appears that they are closely coupled. The interpretation of these events in terms of energy flow may depend on the observed direction of propagation of the auroral hiss. If auroral hiss is propagating upward (as recently reported by Gurnett and Frank), then it is possible that auroral kilometric radiation is just auroral hiss which has escaped from the earth. If the auroral hiss is propagating downward as indicated by low altitude satellites, then it would appear that auroral hiss may directly be associated with the generation of auroral kilometric radiation.

KINTNER, PAUL M., and DONALD A. GURNETT
 Evidence of Drift Waves at the Plasmapause
J. Geophys. Res., 83, 39-44, 1978

As the Hawkeye 1 spacecraft crosses the plasmapause at high altitudes ($R > 3 R_E$), a band of electric field noise is often detected in the frequency channels from 1.7 to 178 Hz. No corresponding magnetic field noise is detected, indicating that the noise is electrostatic (or at least quasi-electrostatic), and the electric field is polarized perpendicular to the plasma density gradient. The noise is only detected when the scale length of the plasmapause is $0.1 R_E$ or less, indicating that a large density gradient is required to produce the noise. These characteristics are all consistent with the interpretation that this noise consists of electrostatic waves excited by the drift mode instability. By using reasonable assumptions concerning the wavelengths of these waves the observed frequency spectrum can be explained as being due to Doppler shifts caused by spacecraft motion through the plasma

KINTNER, P. M., K. L. ACKERSON, D. A. GURNETT, and L. A. FRANK
 Correlated Electric Field and Low-Energy Electron
 Measurements in the Low-Altitude Polar Cusp
J. Geophys. Res., 83, 163-168, 1978

Correlated electric field and low-energy electron measurements are presented for two passes of Hawkeye 1 through the south polar cusp at 2000-km altitude during local morning. In one case the electric field reversal coincides with the boundary of detectable 5.2-keV electron intensities and the equatorward boundary of the cusp. In the other case the electric field reversal and the 5.2-keV electron trapping boundary coincide, but the equatorward edge of the cusp as determined from the presence of 180-eV electron intensities is 5° invariant latitude equatorward of the electric field reversal. We conclude that in the second case, electron intensities associated with the polar cusp populate closed dayside field lines, and hence the corresponding equatorward edge of these electron intensities is not always an indicator of the boundary between closed dayside field lines and polar cap field lines.

GURNETT, D. A., M. M. BAUMBACK, and H. ROSENBAUER
Stereoscopic Direction Finding Analysis of a Type III
Solar Radio Burst: Evidence for Emission at $2f_p^-$
J. Geophys. Res., 83, 616-622, 1978

Stereoscopic direction finding measurements from the Imp 8, Hawkeye 1, and Helios 2 spacecraft over base line distances of a substantial fraction of an astronomical unit are used to directly determine the three-dimensional trajectory of a type III solar radio burst. By comparing the observed source positions with the direct in situ solar wind plasma density measurements obtained by Helios 1 and 2 near the sun the relationship of the emission frequency to the local plasma frequency can be determined directly without any modeling assumptions. These comparisons show that the type III radio emission occurs near the second harmonic, $2f_p^-$, of the local electron plasma frequency. Other characteristics of the type III radio emission, such as the source size, which can be obtained from this type of analysis are also discussed.

GURNETT, DONALD A., and JAMES LAUER GREEN
On the Polarization and Origin of Auroral Kilometric
Radiation
J. Geophys. Res., 83, 689-696, 1978

Observations of radio emissions by the Hawkeye 1 satellite at low altitudes over the southern hemisphere have now provided measurements at radial distances from about 1.5 to 2.5 R_E along the auroral field lines, in the region where the intense nightside auroral kilometric radiation is believed to be generated. These measurements provide new evidence on the mode of propagation and origin of the auroral kilometric radiation. At low altitudes the auroral kilometric radiation is consistently observed to have a low-frequency cutoff at the local electron gyrofrequency f_{ce} . Since the electron plasma frequency f_p^- is usually much smaller than f_{ce} in the region where these observations are obtained, this cutoff corresponds closely with the propagation cutoff for the right-hand mode of propagation. These observations therefore provide a strong indication that the auroral kilometric radiation is right-hand polarized in agreement with previous conclusions made on the basis of the angular distribution of this radiation. In the local evening region, where the intense auroral kilometric radiation is believed to be generated, a few events have been detected for which no low-frequency cutoff is evident. In these cases the auroral kilometric radiation appears to merge essentially continuously into a band of intense auroral hiss which extends downward to frequencies as low as 1 kHz. These observations suggest that the generation of the whistler mode auroral hiss and the escaping auroral kilometric radiation are very closely related. Possible mechanisms which could produce strong coupling between the whistler mode and the escaping free space electromagnetic modes are discussed.

KURTH, W. S., D. A. GURNETT, and J. D. CRAVEN
Correlative Wave and Plasma Measurements of Intense
Electrostatic Wave Events Near the Plasmapause
EOS, 59, 350, 1978

SR 16

CORRELATIVE WAVE AND PLASMA MEASUREMENTS OF
INTENSE ELECTROSTATIC WAVE EVENTS NEAR THE
PLASMAPAUSE

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Intense electrostatic waves near the local electron plasma frequency (f_p^-) with field strengths greater than 1 mV/m are occasionally detected near the plasmapause by plasma wave instruments on the IMP 6 and Hawkeye 1 spacecraft. The intense events occur at all local times and are found in a wide range of magnetic latitudes, from the equator to at least 50°. An intense band of waves is seen at frequencies from as low as 5.62 kHz to 178 kHz. At the higher frequencies the noise is probably upper-hybrid-resonance noise. At the lower frequencies the band

of intense waves is near $3f_{ce}^2/2$, where f_{ce}^- is the local electron gyrofrequency. Polarization measurements indicate the electric field vector of the waves is oriented nearly perpendicular to the geomagnetic field.

Simultaneously with the detection of these electrostatic waves a companion LEPEDE plasma instrument has detected the presence of highly anisotropic distributions of electron intensities. For the several examples gained near the magnetic equator, the relative maxima of the distributions are found at pitch angles $\theta \sim 90^\circ$ and for electron energies extending from ~ 1 keV to several-tens of keV. It is likely these energetic electrons are directly associated with the intense electrostatic waves. In addition, some evidence suggests these strong sources of electrostatic waves at the plasmapause may be a secondary source of nonthermal continuum radiation.

CRAVEN, J. D.

Proton Bulk Flow Directions and Magnitudes Within
the Polar Cusp

EOS, 59, 353, 1978

54 46

PROTON BULK FLOW DIRECTIONS AND
MAGNITUDES WITHIN THE POLAR CUSP

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Astronomy, University of Iowa,
Iowa City, Iowa 52242)

The gross characteristics of proton bulk flows within the polar cusp are being investigated by means of observations gained with a LEPEDEA plasma analyzer carried on the Hawkeye satellite. During the summers of 1976 and 1977 measurements of the flow directions and magnitudes were obtained as the satellite traversed the polar cusp near the local-noon-meridional plane at geocentric radial distances of 4.5 to 8.0 R_E . At these distances the polar cusp was distinguished in the measurements

as a region of magnetosheath-like plasma separating the relative plasma void of the polar cap from the more energetic particle populations of the outer zone and ring current. Well-defined flows could be detected over the latitudinal width of the polar cusp for many of the satellite traversals, with the directions of flow aligned nearly parallel or anti-parallel to the local magnetic field vectors. Frequently the flows were observed to be directed earthward near the equatorward boundary of the cusp, with flows directed away from the earth at the more-poleward latitudes. Specific patterns for the flow directions as a function of latitude across the cusp remain elusive, in part due to apparent variations with magnetic activity and local time. Flow magnitudes do appear to be reduced greatly at the lower altitudes.

GALLAGHER, D. L., and D. A. GURNETT

Auroral Kilometric Radiation: Average Source
Position and Distribution

EOS, 59, 362-363, 1978

54 119

AURORAL KILOMETRIC RADIATION: AVERAGE
SOURCE POSITION AND DISTRIBUTION

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The objectives of this study are to locate the average generation regions of auroral kilometric radiation by examining average electric field strengths as a function of position and to describe the distribution of the source regions at frequencies 178 kHz, 100 kHz, and 56.2 kHz. Serving as the basis for the study, satellites Hawkeye-1 and IMP-6 provide seven years of combined orbital coverage over a wide range of latitudes from 1.5 to 30 earth radii.

Average spectral power as a function of position has been obtained by long term averages over all usable electric field data from both satellites. Where auroral kilometric radiation is expected to be found, plots of average power versus geocentric radial distance show a power law dependence between four and twenty-five earth radii. At large distances the plots show the expected $1/r^2$ dependence, whereas close to suspected source regions the power flux increases more rapidly than $1/r^2$. Preliminary results indicate the average source regions lie within seven earth radii, at high latitudes, and between twenty-one hours and twenty-four hours magnetic local time. To the extent that additional investigations are complete, comment will be made on a more accurate determination of source positions, source distribution, and the dependence of source position on frequency.

CHEN, T.-F., B. A. RANDALL, and J. A. VAN ALLEN

The Geomagnetic Field at Large Radial Distances as
Observed by Hawkeye I

EOS, 59, 364, 1978

54 126

THE GEOMAGNETIC FIELD AT LARGE RADIAL DIS-
TANCES AS OBSERVED BY HAWKEYE I

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An extensive body of observations of the geomagnetic field vector at large radial distances has been obtained by the University of Iowa satellite Hawkeye I since 3 June 1974. The orbit of this spinning satellite is in a plane inclined at 90° to the earth's equatorial plane, with apogee at about 21 R_E over the

north pole, semimajor axis 11 R_E , and period 51.5 hours. A new empirical model of the topology of the distant geomagnetic field is presented, with emphasis on the noon-midnight meridian plane. The polar cusp is a clearly defined feature, extending over a longitudinal range of about $\pm 30^\circ$ from the noon meridian. The mean configurations of the bow shock and magnetopause are obtained from several hundred traversals and the electrical current systems on these two surfaces are inferred for a selected set of traversals. One of the most interesting features of the current system is the toroidal current encircling the polar cusp. The physical thicknesses of the bow shock and magnetopause are found and estimates are made of the velocities and extents of the motion of these fluctuating surfaces.

CHEN, TSAN-FU

The Earth's Magnetic Field at Large Radial Distances
as Observed by Hawkeye 1
Ph.D. Thesis, May 1978

The geomagnetic field has been observed during a period of over three and one-half years with a three-axis fluxgate magnetometer on the University of Iowa satellite Hawkeye 1 since its launch on 3 June 1974 into a highly eccentric orbit with apogee at about $21 R_E$ (earth radii) over the north polar cap of the earth. Data up to the end of August 1976 have been used in this thesis. Supplemental data from IMP-6 during the first seven months of 1974 were also used. The geocentric distances of the bow shock and magnetopause, respectively, are $14.6 (\pm 2.0) R_E$ and $10.2 (\pm 1.5) R_E$ at the subsolar point; and $23.0 (\pm 2.4) R_E$ and $14.1 (\pm 1.8) R_E$ in the dawn-dusk meridian plane, the quoted ranges being real r.m.s. fluctuations of position, not uncertainties of measurement.

A new model of the distant geomagnetic field is derived from the observations and described in both Geocentric Solar Magnetospheric (GSM) and Geocentric Magnetic Equatorial (GME) coordinates. In the latter coordinate system [Hedgecock and Thomas, 1975], the magnetic topology of the polar cusp is displayed in a more satisfactory manner. A solenoidal system of electrical currents encircling the polar cusp is determined for the first time as is the current system on the bow shock. Typical magnitudes of the surface current density at the equatorward boundary of the cusp are 40 milliamperes/meter. This circulating current, counterclockwise as viewed from the sun, is attributed to the diamagnetic effect of plasma, intruding from the magnetosheath into the cusp. On the bow shock, typical surface current densities are 15 milliamperes/meter. Thicknesses of the magnetopause and bow shock are typically 150 and 10 km, respectively. The fluctuating velocity of the latter is from 1 to 10 km/sec and its excursion is of the order of several hundred to a few thousand km under relatively quiescent conditions.

GURNETT, D. A., and L. A. FRANK

Plasma Waves in the Polar Cusp: Observations from
Hawkeye 1
J. Geophys. Res., 1978 [in press]

In this paper we investigate the characteristics of plasma waves observed by the Hawkeye 1 spacecraft in the vicinity of the polar cusp. The primary types of plasma waves associated with the polar cusp are (1) a band of ULF-ELF magnetic noise extending from a few Hz to several hundred Hz, (2) a broad-band electrostatic emission extending from a few Hz to about 30 to 100 kHz, with maximum intensities at about 10 to 50 Hz, (3) electrostatic electron cyclotron waves near the electron gyrofrequency and (4) whistler-mode auroral hiss emissions. Of these various types of waves, only the ULF-ELF magnetic noise is uniquely associated with the cusp in the sense that the noise can be used as a reliable indicator of the polar cusp region. All of the other types of plasma waves occur in regions adjacent to the polar cusp as well as in the cusp itself.

Spectrum measurements often show that the ULF-ELF magnetic noise extends up to, but does not exceed, the local electron gyrofrequency, f_{ce} . This upper cutoff strongly suggests that the noise consists of whistler-mode electromagnetic waves. The mechanism for generating these waves remains highly uncertain, however, since the electron angular distribution in the cusp is usually not sufficiently anisotropic to account for these waves by the well known whistler-mode cyclotron resonance instability. Other mechanisms, such as turbulence generated by the Kelvin-Helmholtz instability or by a drift wave instability, have also been suggested to generate this noise. The broad-band electrostatic noise is believed to be caused by a current-driven electrostatic instability (ion-cyclotron or ion-acoustic) of the type widely believed to occur in auroral field-aligned current systems. The mechanisms for generating electron cyclotron waves and auroral hiss emissions are believed to be reasonably well understood, based on previous studies of these emissions in other regions of the magnetosphere.

GURNETT, DONALD A.

Electromagnetic Plasma Wave Emissions from the Auroral
Field Lines

J. Geomagnetism and Geoelectricity, 1978

[submitted for publication]

Several types of electromagnetic waves are known to be emitted by charged particles on the auroral field lines. In this paper we review the most important types of auroral radio emissions, both from a historical perspective as well as considering the latest results. Particular emphasis is placed on four types of electromagnetic emissions which are directly associated with the plasma on the auroral field lines. These emissions are (1) auroral hiss, (2) saucers, (3) ELF noise bands, and (4) auroral kilometric radiation. Ray tracing and radio direction finding measurements indicate that both the auroral hiss and auroral kilometric radiation are generated along the auroral field lines relatively close to the earth, at radial distances from about 2.5 to 5 R_E , probably in direct association with the acceleration of auroral particles by parallel electric fields. The exact mechanism by which these radio emissions are generated has not been firmly established. For the auroral hiss the favored mechanism appears to be amplified Cerenkov radiation. For the auroral kilometric radiation several mechanisms have been proposed, usually involving the intermediate generation of electrostatic waves by the precipitating electrons.

KURTH, W. S., D. A. GURNETT, and F. L. SCARF

High Resolution Spectrograms of Ion-Acoustic Waves
in the Solar Wind

J. Geophys. Res., 1978 [to be submitted]

Ion-acoustic waves, similar to those detected by the Helios spacecraft from 0.3 to 1.0 AU, have now been detected by the Voyager spacecraft in the solar wind out to heliocentric radial distances of 1.7 AU. High bit rate waveform measurements provide the first high resolution, frequency-time spectrograms of these waves. The Voyager spectrograms show that the ion-acoustic waves consist of narrow-band bursts which last for a few seconds or less. The center frequency of the bursts can fluctuate rapidly in frequency, usually in the range between the electron and ion plasma frequency, f_p^- and f_p^+ . (These waves have been previously referred to as $f_p^- < f < f_p^+$ noise.)

Comparisons of the high resolution spectrograms from the Voyager spacecraft with similar measurements from earth-orbiting spacecraft show that spectra of the ion-acoustic waves in the solar wind at 1.7 AU are identical to spectra of short wavelength ion-acoustic waves detected upstream of the earth's magnetosphere. The latter waves have been associated with protons streaming into the solar wind from the bow shock. This close similarity strongly suggests that the ion-acoustic waves detected in the solar wind by Helios and Voyager are driven by an ion beam instability, as has recently been suggested in a theoretical analysis by Gary.

CRAVEN, J. D., and L. A. FRANK
Distribution of Plasma in the Polar Magnetosphere
Observed with Hawkeye 1
J. Geophys. Res., 1978 [to be submitted]

CRAVEN, J. D., and L. A. FRANK
Some Systematic Features of Proton Intensities Within
the Polar Cusp
J. Geophys. Res., 1978 [to be submitted]